4

GEOLOGY OF THE CASTERTON DISTRICT

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[Read 14 July 1955]

Contents

Introduction

The town of Casterton is situated in the valley of the Glenelg River in south-western Victoria, 224 miles by road from Melbourne. The area to be described lies to the north of Casterton and occupies the south-western corner of the County of Dundas (Locality map, Fig. 4). This area, at an average elevation of about 600 ft., forms a part of the Dundas Tabelands (Boutakoff, 1952) and is in the process of dissection by streams which flow south-westerly to join the Glenelg River.

Early references to the metamorphic rocks of this area were made by Dennant (1885), who recorded grey slates at Roseneath* and green serpentine rocks at the Hummocks, a mile north-west of Wando Vale. Dennant also gave brief descriptions of granitic rocks from Harrow, Dergholm, Wando Vale and Carapook in 1893. Metamorphic rocks in Upper Steep Bank Rivulet were observed by Ferguson (1894, p. 59), who suggested that these were older than and unconformable to the slates of Nolan Creek a few miles further west. In this he was supported by Stirling (1898), who traversed the area from east to west and noted the rather abrupt passage from biotite schists to slates. In 1912 Dunn advanced the suggestion that the schists in the gorge of the Wando River, ten miles north-east of Casterton, actually represented Ordovician rocks metamorphosed by adjacent granites, but fossil evidence of the age of the slates had not been obtained.

A Geological Camp was conducted in the district in 1914 and the physiography of the area, investigated during this camp, has been described by Fenner (1918). Some additional detail on the metamorphic rocks is provided by Krausé (1886) and by Skeats (1909 and 1935).

General Geology

The metamorphic and granitic rocks of this area, for which the general name Glenelg River Complex is proposed, are for the greater part concealed beneath younger deposits, which, although they have not been studied in detail, have been mapped in the field (Fig. 5) and are described briefly below. The metamorphic rocks, which include both sedimentary and igneous types, have been traced through a series of zones marked by the successive development of biotite, almandine and staurolite in pelitic and dolomitic pelitic rocks. Although the prevailing strike (NW-SE) does not permit individual beds to be followed through successively higher metamorphic grades, broad rocks groups can be recognized throughout the zones.

A. Sedimentary Rocks of the Glenelg River Complex

1. Pelitic and Psammitic Rocks

Slate. Grey laminated slates, which weather typically to yellow and are commonly spotted with limonite after pyrite, are found in the valley of the Glenelg River, extending north from Roseneath Homestead for four miles. South-east of Roseneath, slates outcrop along the Glenelg River for two miles, beyond which they are obscured by Jurassic sediments. Further to the east, lustrous black slates in Steep Bank Rivulet a mile west of the biotite isograd dip steeply to the south-west and occasionally show graded bedding. Here the slates are interbedded with narrow bands of quartz-graywacke, and further to the north-east give place to dolomitic slates. At Retreat Homestead on the Glenelg River, fine-grained laminated slates are composed largely of sericite flakes and quartz grains (No. 7795). (*Numbers refer to thin sections in the collection of the Geology Department of the University of Melbourne.*)

Graywacke. A quartz-graywacke formation of the order of 2000 ft. in thickness strikes across the area in a NW-SE direction. In the gorge of Harvesters Creek graded beds reach a thickness of 1 ft. and have almost vertical dip. This grading maintains a constant south-west facing across the formation. Joints in the graywacke dip at a low angle to the south-east. Where the southern boundary of the formation can be observed, as at a locality three miles east of Dergholm, it appears to be a normal contact.

* Roseneath is 5 miles SSE of Dergholm.

The quartz-graywackes are free from lithic fragments, and thin coarser layers contain flakes of muscovite up to 2 mm., with sub-angular grains of microline, oligoclase, strained quartz and rare calcite in a matrix of quartz, chlorite and sericite. Apatite, zircon and brown tourmaline are accessory (Nos. 7798, 7799). Calcite becomes more prominent in the finer layers of the graded beds.

Narrow bands of similar quartz-graywacke are intercalated with slates further to the north-east in Steep Bank Rivulet. Here, however, they show cataclastic textures such as undulose extinction, while deformation lamellae in quartz have been produced in a vein which traverses section No. 7806 (Pl. XI, fig. 1). Thin beds of lithic graywacke are interbedded with slates at locality 38.2, 75.8*, and contain sub-angular volcanic rock particles up to 1 mm. accompanied by grains of twinned- and chequer-albite, a little biotite and epidote and possible chert particles.

Quartzite. Bedded chert has not been found in the area but narrow lenses of microcrystalline quartzite, at the most a foot in width, accompany dolomitic slates in Mitchell's Creek and may possibly represent original cherts (e.g. No. 7803). Similar rocks are found at a higher metamorphic grade interbedded with biotite schists in the road cutting on Cashmere Hill.

Biotite-muscovite phyllite. Pelitic and semi-pelitic rocks have a wide occurrence to the north-east at higher metamorphic grades, but metamorphic equivalents of the major quartz graywacke formation are not clearly recognizable. The entry of biotite, which marks the position of the biotite isograd, takes place in slates which are dolomitic. Also within the biotite zone biotite-muscovite phyllites represent aluminous slates while biotite-muscovite-quartz schists correspond to silicious pelites or to rocks in which narrow pelitic and psammitic bands occurred side by side.

Biotite-muscovite phyllites outcrop in Mitchell Creek, half a mile east of the biotite isograd, and contain porphyroblasts of brown biotite reaching 0·25 mm. interleaved with chlorite in a matrix of sericite flakes disposed parallel to the bedding (Nos. 7827, 7828).

Biotite-muscovite-quartz schist. Biotite-muscovite-quartz schists low in the biotite zone in Steep Bank Rivulet contain narrow sedimentary laminae of quartz which alternate with bands composed of muscovite and biotite (No. 7829). At a higher metamorphic grade in Vines Creek weathered biotite schists (No. 7830) are made up of biotite and quartz with a little chlorite and muscovite. Biotite-quartz schists containing a little muscovite outcrop among the intrusive rocks in the gorge of the Wando Vale Ponds at the Hummocks.

To the north-east of the southern intrusion of Wando Granodiorite biotite-muscovite-quartz schists are exposed in the valley of the Wando River. Here biotite flakes reach 0·15 mm. and define a pronounced schistosity. Quartz, and a little brown tourmaline are the remaining constituents, with muscovite occasionally appearing as prophyroblasts set across the schistosity plane. Lenticular quartz veins follow the schistosity surface (Nos. 7832, 7833). A higher proportion of quartz is found in psammitic schists intercalated with biotite schists in Mitchell Creek, where biotite and muscovite make up only about 10 per cent of the rock. The mineral chloritoid may be expected in rocks of the albite-epidote amphibolite and greenschist facies which have compositions similar to rocks carrying staurolite at higher grades, but no chloritoid was found in the district.

* Localities are expressed as grid references to map, Fig. 5.

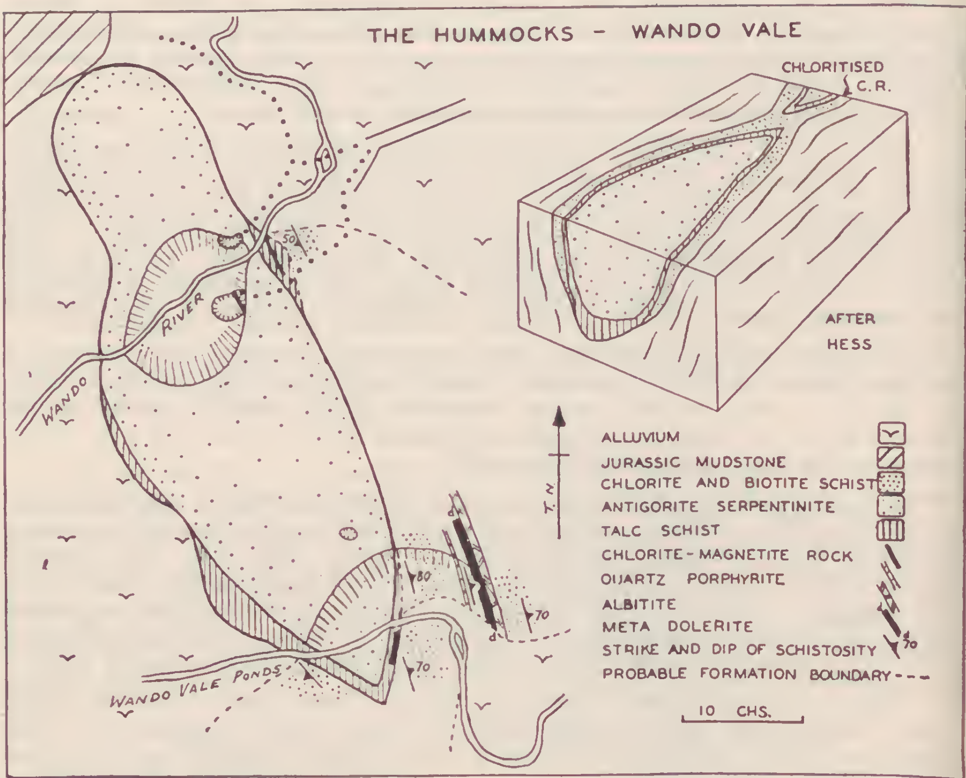

Fig. 1.—Rock distribution in the gorges of the Wando River and the Wando Vale Ponds at the Hummocks. *Inset*: Talc deposit type steatitization of ultra-basic rocks.

Biotite-muscovite-quartz schists which may also contain plagioclase are widely distributed in the area to the north-east of the northern intrusion of the Wando Granodiorite and although no close examination of these has been made, they probably lie within the chlorite-biotite subfacies. These rocks are found in the upper parts of Boundary Creek, the Wando River and Robertson Creek.

Andalusite-biotite-muscovite-quartz schist. A sporadic development of andalusite is found within the biotite zone but is a more common feature of higher grade rocks. At locality 42.0, 79.0, biotite schists contain conspicuous porphyroblasts of andalusite which reach a length of 3 cm. and stand out with random orientation from the weathered schistosity surfaces of the outcrops. In thin section (Nos. 7835, 7835A) colourless andalusite containing carbonaceous matter is partly replaced by sericite (Pl. XI, fig. 2). The groundmass consists of quartz and biotite with subordinate muscovite. Porphyroblasts of chlorite up to 0·9 mm., secondary after biotite, contain needles of rutile and relict pleochroic haloes.

Almandine-biotite-quartz schist. As pelitic rocks are followed in a north-easterly direction red garnet makes a sudden appearance in Vines Creek, the Wando River, Beauty Creek, and in Robertson Creek further to the south-east. Although the chemical composition of the mineral is not known, its abundance and the fact that the plagioclase in associated rocks is more basic than albite suggest that the garnet is almandine and not a manganiferous variety proper to a lower metamorphic grade. The width of the almandine zone is, however, restricted by the entry of staurolite soon after that of almandine.

Yellow-brown schists in Mitchell Creek, at locality 39.8, 82.0, contain garnet crystals a little more than 1 mm. in diameter and readily visible in the hand specimen. Staurolite is absent, and these rocks are adjoined to the south-west by biotite schists free from garnet. In thin section No. 7885 idioblastic garnet, brown biotite and chlorite are contained in a groundmass of quartz and plagioclase granules, the plagioclase occasionally twinned.

Staurolite schist. Schists which contain staurolite are restricted, as far as is known, to two localities situated in the valleys of Vines Creek and the Wando River. These are taken to define the south-western boundary of the staurolite zone, but the higher grade index minerals kyanite and sillimanite were not found in the district.

In specimens from Vines Creek (Nos. 7874, 7875) porphyroblasts of staurolite, pleochroic from pale yellow to deep yellow and sieved with quartz, average 1·5 mm. in length and are partially replaced by sericite. Subidioblastic almandine reaches 1 mm. and is associated with muscovite and biotite. The groundmass is a granoblastic mosaic of quartz and a little untwinned plagioclase. In some cases the replacement of staurolite by sericite has been complete and the presence of staurolite rather than of andalusite can be inferred only by the sieved nature of the original crystal. These specimens contain the assemblage plagioclase-muscovite-staurolite-almandine-biotite-quartz.

Schists containing the assemblage staurolite-almandine-biotite-quartz are found in the Wando River at locality 42.6, 79.5. In section No. 7876 relics of staurolite surrounded by sericite (Pl. XI, fig. 3) are accompanied by almandine and biotite in a groundmass of xenoblastic quartz and a little brown tourmaline.

Staurolite schists without almandine are represented by section No. 7877, a muscovite-staurolite-quartz-biotite schist.

Andalusite schist. Within the staurolite zone almandine-biotite-andalusite schists and rocks consisting essentially of andalusite and sericite are found in the Wando River area and in Robertson Creek but andalusite-staurolite schists have not been encountered.

Prisms of andalusite reach a length of 3 cm. in a specimen of coarse andalusite-sericite rock, No. 7878. In thin section radiating flakes of sericite surround relics of colourless andalusite. Chlorite, muscovite, quartz and iron ores are present in subordinate quantities. Porphyroblasts of andalusite in golden brown garnet schists from the bed of Boundary Creek, south-east of Wando Homestead, have been largely replaced by sericite. Only a few small relics of andalusite remain and biotite is in the process of replacement by chlorite and rutile. A little muscovite is present in the quartz mosaic.

In the gorge of Robertson Creek in the south-east of the area a strip of garnetiferous pelitic schists includes andalusite schists in which the andalusite again occurs as scattered relics surrounded by sericite (No. 7880).

2. Calcareous and Dolomitic Rocks

Argillaceous dolomitic limestone. Slates containing carbonate minerals were recorded from this area by Ferguson (1894, p. 59), who drew attention to "two bands of shaly marble" in Nolan Creek. Low-grade carbonate rocks grading from impure dolomitic limestones to dolomitic slates outcrop widely to the east of Nolan Creek and were also found two miles north-west of Roseneath Homestead, where dark grey argillaceous dolomites occur, consisting of dolomite grains reaching 0·01 mm. in diameter, accompanied by sericite, quartz and a little brown tourmaline.

Dolomitic slates similar to the rocks of Nolan Creek outcrop in the bed of Mitchell Creek and in Steep Bank Rivulet. These rocks are laminated, with dolomite-quartz bands alternating with darker bands of chlorite and opaque matter, and have been tightly folded. A lustrous cleaved dolomite from Steep Bank Rivulet (No. 7804) contains quartz grains and shreds of sericite which define the cleavage direction. The rock is veined with quartz and contains a few cubes of pyrite.

As the grade of metamorphism increases, biotite flakes develop to produce lustrous dolomitic phyllites. The early growth of biotite is illustrated in section No. 7823, in which biotite flakes reach a length of 0·06 mm. The remainder of the rock consists of grains of quartz and dolomite which rarely exceed 0·03 mm. in diameter, and are associated with sericite, chlorite and accessory apatite. The enlargement of biotite flakes in dolomitic phyllites is represented in sections Nos. 7824 and 7825. Calcite accompanies the dolomite in rock No. 7825.

Calc-biotite schist (*No. 7826*). Banded calc-biotite schists are found high in the biotite zone near the head of Deep Creek, where they are interbedded with pelitic biotite-quartz schists. Bands consisting essentially of biotite and a little quartz alternate with bands of recrystallized calcite grains which appear lozenge-shaped in sections cut in the plane normal to the fold axis. Quartz accompanies the calcite to the extent of about 20 per cent.

In this rock, originally a chloritic calcareous shale, epidote has not been produced, although the proportion of biotite is quite significant (Harker 1937, p. 261).

Actinolite schist. Although the most common actinolite-bearing rocks in the area have been derived from basic intrusives, there are examples of sedimentary schists containing actinolite. These are characterized by banded textures and by abundant quartz. They can occasionally be seen to pass laterally into sedimentary biotite-muscovite-quartz schists. These rocks resemble the hornblende garbenschiefer and contain bladed crystals of actinolite in stellate arrangements as a result of mimetic crystallization. Where the groundmass is in part felspathic and the rocks occur in the vicinity of basic intrusives, ambiguous cases arise and actinolite schists may then represent narrow intrusives or sedimentary rocks in which tuffaceous material was present.

Sedimentary actinolite schists do not make their appearance until the top of the biotite zone is reached. Laminated actinolite-biotite-quartz schists from the south bank of the Wando River (No. 7837) contain bands of quartz and biotite with intervening bands composed of biotite and green actinolite whose bladed crystals reach 2 mm. Sphene is accessory. At this locality actinolite rocks grade into biotite schists and the sedimentary nature is beyond doubt.

Hornblende garbenschiefer, in which groups of radiating actinolite prisms are set in a granoblastic quartz groundmass containing apatite and sphene, are represented by the sections Nos. 7840 and 7841. The prisms of amphibole may reach 0·5 cm. and in the latter section sericitized plagioclase occurs in the groundmass.

The presence of minerals of the epidote group gives rise to such rocks as hornblende-clinozoisite-quartz schist (No. 7842). Quartz-rich layers alternate with darker layers of clinozoisite and green hornblende, and occasionally with bands of clinozoisite alone.

These schists have evidently arisen from impure arenaceous rocks containing calcite and chlorite (Harker 1937, p. 270).

Hornblende-quartz shist. Dense schistose rocks composed very largely of hornblende outcrop in the Wando River at the position of the almandine isograd. Hornblende porphyroblasts, sieved with quartz and sphene, are contained in a groundmass of quartz, muscovite, apatite and sphene with occasional biotite and iron ore (Nos. 7868, 7869). Although distinct bedding could not be traced at this locality, the rocks are regarded as derivatives of calcareous sediments and related to the actinolite-biotite schists described above.

Similar rocks can be recognized at higher grades. At locality 42.9, 79.5, in the Wando River hard bluish-grey banded hornblende schists are veined with recrystallized calcite. A plagioclase amphibolite from this locality contains hornblende and iron ores on the one hand and xenoblastic quartz and untwinned plagioclase on the other in bands 5 mm. in thickness. Sphene, biotite, chlorite and apatite are accessory (Nos. 7890, 7891). These schists are regarded as sediments on account of their banded textures and the abundance of biotite which they contain. A strip of similar rocks outcrops to the west of Robertson Creek at locality 46·5, 75·0.

Hornblende-garnet schist. Garnetiferous hornblende schists are found at only one locality (45.3, 78.5). Here a laminated sedimentary schist contains the assemblage plagioclase-hornblende-almandine-biotite-quartz. Biotite flakes and bladed crystals of sieved hornblende are associated in a groundmass of quartz, untwinned plagioclase and sphene. Garnet idioblasts reach 1·5 mm. in diameter and contain inclusions of biotite and hornblende (No. 7893).

Diopside calc-silicate rocks. In the highest metamorphic grades impure dolomitic limestones are represented by hard calc-silicate rocks without schistosity. The most extensive outcrops are found in the gorges of Robertson Creek and Corea Creek. Rocks of a similar type have been reported in the metamorphic complex of north-eastern Victoria and southern N.S.W. by Joplin (1942, p. 171) and by Tattam (1929, p. 27).

Diopside is the characteristic mineral in calc-silicate rocks from the Casterton area. The simplest group consists of diopside, quartz and plagioclase. A hard greenish-grey rock without banding from Robertson Creek (No. 7894) contains about 20 per cent of colourless diopside as scattered xenoblastic grains in a mosaic of quartz and partly sericitized andesine with accessory sphene.

A little green hornblende may enter in rocks of this type. Section No. 7896 contains seams of biotite and hornblende which alternate with seams of hornblende and diopside. The groundmass contains in each case quartz and medium andesine with accessory sphene.

Orthoclase is prominent in quartz-plagioclase-diopside rocks and also in rocks containing hornblende. It is generally confined to the groundmass as xenoblastic grains but occasionally encloses granules of diopside poikiloblastically (Nos. 7897, 7898). Twinned acid labradorite in these sections is much less abundant than orthoclase. A little apatite, sphene, quartz, hornblende, calcite and biotite may also occur.

A greater proportion of hornblende in section No. 7900 has led to the assemblage plagioclase-hornblende-diopside-orthoclase-epidote-quartz in which orthoclase again predominates over plagioclase.

Banded calc-silicate rocks are found in the Wando River Valley at locality 43·3, 79.9. Narrow beds, parallel in attitude to the regional foliation of neighbouring schists, show a richness in any of diopside, hornblende or biotite. In some bands a small quantity of calcite occurs, as in section No. 7901, which contains in addition hornblende and diopside with xenoblastic orthoclase, quartz and andesine. Orthoclase is not restricted to any particular band; apatite and sphene are accessory.

At this locality, calc-silicate rocks have been intruded by a quartz diorite dyke and as this is approached the banding of the sediments is complicated by narrow igneous seams of twinned andesine, hornblende, quartz and sphene between the granular sedimentary layers. The sedimentary origin of these rocks is supported by their abundance of potash felspar and quartz. The pronounced banding, with a selective development of different minerals in bands, suggests that the original composition has determined which of pyroxene or hornblende may form. This may reflect variations in the proportion of calcite and dolomite in the original sediments.

Scapolite has been detected at two localities in the area. A specimen from south-eastern Robertson Creek (No. 7706) has a speckled appearance in the hand specimen which is due to patches of quartz-scapolite in a diopside rock. In thin section the rock contains ragged poikiloblasts of zoisite. Diopside is sieved with hornblende, quartz and untwinned plagioclase while scapolite is also strongly sieved with quartz and plagioclase of the groundmass. Calcite, apatite and sphene are present in minor quantities.

A rock containing zoisite, diopside, scapolite, orthoclase and calcite is found at the lower end of Corea Creek Gorge (No. 7907—for locality see Fig. 2). In hand specimen, folded layers an inch or more in thickness containing white prismatic scapolite are separated by argillaceous beds of similar thickness. The prismatic habit of the scapolite is more clearly visible in thin section (Pl. XI, fig. 4) and a refractive index value of $\omega = 1{\cdot}611$ suggests a composition close to meionite. The adjacent argillaceous beds contain biotite and diopside in a groundmass of orthoclase, plagioclase, quartz and rare sphene.

The calc-silicate rocks of this area are in general not deficient in silica and they have arisen from impure argillaceous magnesian limestones. The co-existence of quartz and calcite indicates that wollastonite is unstable under the conditions of metamorphism and the presence of minerals of the epidote group favours the stress condition of the staurolite-kyanite subfacies. The formation of a scapolite mineral rich in calcium and carbonate in an impure limestone may be due to metamorphism alone with the addition only of CO_2.

3. Pyroclastic Rocks

Ash and tuff. Finely banded ashes are exposed at river level in Steep Bank Rivulet at Locality 34.6, 81.8, but are of limited extent. In places they are calcareous. These are the only sediments of their kind noted in the area. No decisive examples of ancient volcanic rocks have been found. The absence of such primary features as pillow structures and vesicles allies the basic rocks of this district with intrusive dolerites.

B. Igneous Rocks of the Glenelg River Complex

1. Quartz Porphyrite

West of the biotite zone, dykes of pale cream quartz porphyrite up to 30 ft. in thickness are intruded into slightly dolomitic slates. These contain quartz up to 0·2 mm. in a groundmass of sericitized felspar laths, which have a composition close to albite. Phenocrysts of plagioclase reach 0 5 mm. and have been replaced by albite and sericite (Nos. 7808, 7809, 7810).

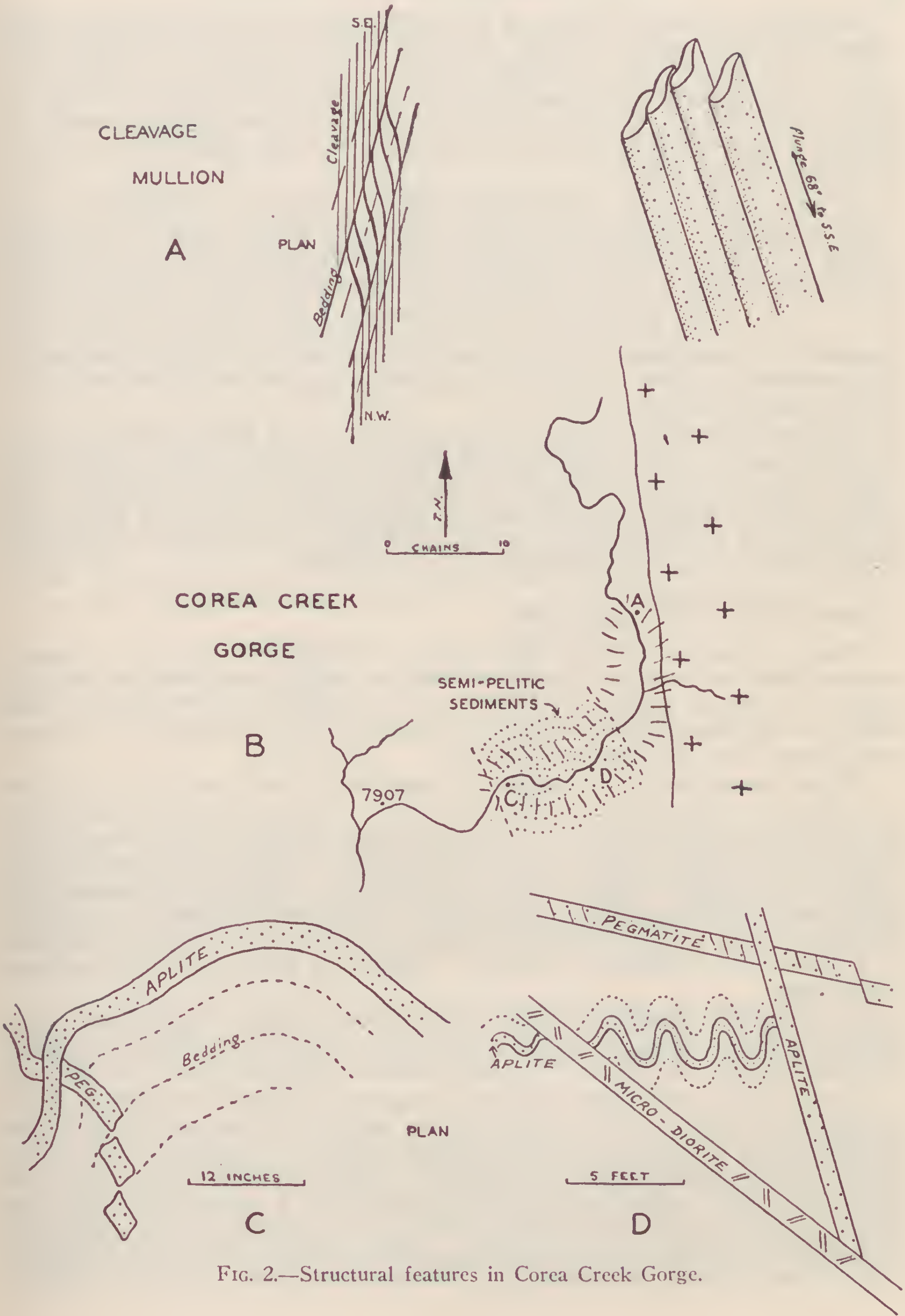

Fig. 2.—Structural features in Corea Creek Gorge.

Boulders of a cleaved yellow rock (No. 7843) in which the cleavage planes are marked by a development of minute muscovite flakes are found in the gorge of the Wando Vale Ponds at the Hummocks (Fig. 1). The occurrence of phenocrysts of corroded plagioclase and strained quartz in a groundmass of plagioclase laths and quartz grains indicates the igneous character of the rock, although the structure is completely obscured in the field. This rock is a biotite zone equivalent of the lower grade quartz porphyrite.

In the almandine zone, steeply dipping bands, several feet in thickness, of pale cream quartzofelspathic schist show sharp boundaries without gradation into pelitic schists. The texture of the groundmass is granoblastic but these rocks are regarded as dykes injected prior to the folding and equivalent to the quartz porphyrite series. In section No. 7870 muscovite flakes of average length 0·08 mm., lenticular aggregates of biotite and poikiloblastic garnet with quartz and plagioclase inclusions are contained in a granoblastic mosaic of quartz and untwinned sericitized plagioclase. Larger twinned felspars of uncertain composition suggest original felspar phenocrysts in an igneous rock.

The same pale cream schistose rocks can be traced in higher grades and subidioblastic garnet is a frequent accessory mineral (No. 7887), again contained in a groundmass of xenoblastic quartz and untwinned plagioclase approximately equal in amount. Xenoblastic orthoclase may be present in some cases and sphene may be accessory in the groundmass. Garnet-free types in the staurolite zone contain potash felspar in excess of plagioclase (Nos. 7888, 7889).

2. Meta-dolerite and Amphibolite

Basic greenstones in Steep Bank Rivulet and Mitchell Creek are relatively coarse-grained and are free from amygdules and vesicles, suggesting an intrusive origin. The diabase mapped by Caldwell in the parish of Roseneath three miles north-west of Roseneath Homestead is a meta-dolerite or microgabbro of similar type (Mines Dept. Vic. section No. 2713).

Albitic meta-dolerites in the valley of Steep Bank Rivulet, north of its junction with Mitchell Creek reach a thickness of 30 feet. Massive rocks from the centres of intrusions are greenish grey in colour and contain spherical clots of recrystallized albite. Relict primary augite in section No. 7813 is ophitically intergrown with twinned albite laths reaching 3 mm. in length, and plagioclase is saussuritized. Pale green actinolite surrounds augite relics, while irregular patches of chlorite enclose needles of actinolite. Skeletal crystals of ilmenite are in process of alteration to a fine-grained aggregate of sphene. Calcite and apatite are the remaining constituents.

At the sheared boundaries of the dykes no trace of augite remains and in thin section granulated albite grains are surrounded by streaks of chlorite and green actinolite studded with iron ore. Calcite is associated with the albite (No. 7817).

A more pronounced ophitic texture is preserved in section No. 7814 in which pyroxene has been completely replaced by actinolite. These rocks have been produced from a dolerite free from original olivine and contain the assemblage actinolite-chlorite-epidote-albite-calcite-sphene. They can be grouped under the general heading of chlorite-epidote-albite amphibolites, a subdivision of the low grade epidiorites described by Wiseman (1934, p. 377) from the Scottish Highlands.

Rocks which do not contain actinolite and thus fall into the group of chlorite-albite schists contain the assemblages chlorite-albite-sphene and chlorite-albite-calcite. As an example of the first type, section No. 7816 contains twinned, crushed albite laths up to 6 mm. in length and chlorite, associated with a few flakes of talc, to the exclusion of actinolite. Iron ores and sphene are relatively abundant.

Within the biotite zone albite is still the stable plagioclase felspar in the meta-dolerites, and relict igneous textures are generally preserved. Albite-biotite-chlorite schists are the predominant derivatives of doleritic rocks and do not contain actinolite. Section No. 7844, an example of this type, contains crushed albite laths containing inclusions of apatite and chlorite, irregular shreds of green chlorite and accessory iron ores. Contortion of albite twin lamellae and pronounced undulose extinction in albite attest to strong post-intrusion deformation. Chlorite may not be present in the assemblage in meta-dolerites from the biotite zone, and rocks consisting essentially of albite-biotite, in which albite laths make up about 20 per cent of the volume, are known from Harvesters Creek (No. 7847).

In the gorge of the Wando Vale Ponds at the Hummocks an abundance of zoisite leads to albite-zoisite-biotite schists (No. 7848) in which dusty albite laths, brown biotite and iron ores are associated with porphyroblasts of zoisite accompanied by sericite and reaching 3 mm. diameter. The recrystallization of actinolite in low grade meta-dolerites produces porphyroblastic actinolite rocks in the biotite zone in which the original igneous texture of the albite laths is still visible and no relict augite remains. Frayed porphyroblasts of actinolite ($X = Y$ pale green, Z pale bluish green) are set in a groundmass of recrystallized albite and minute needles of actinolite. Traces of clinozoisite occur in scattered granules with apatite, pale brown biotite and ilmenite. In the following mode, determined from a dyke at locality 35.3, 84.3, rather more actinolite is present than is typical of these rocks.

Actinolite	77·0 % by vol.
Albite	16·1
Iron ore	4·3
Apatite	1·5
Biotite	0·9
Clinozoisite	tr.
	99·8

The broad intrusion mapped in Mitchell Creek is of this type, with granules of sphene surrounding crystals of ilmenite (Nos. 7850, 7851). Abundant biotite may accompany actinolite, as in a meta-dolerite from the Wando Vale Ponds (Fig. 1), which contains albite to the extent of 50 per cent of the rock. Here biotite occurs to the exclusion of chlorite and accompanies an amphibole which has a deep bluish green Z absorption colour (No. 7853).

The destruction of the igneous texture takes place to the north-east of the southern granodiorite intrusion, where the groundmass in basic plagioclase amphibolites is made up of equant xenoblastic plagioclase grains, generally without twinning.

At the top of the biotite zone, albite has been confirmed in plagioclase amphibolites in the Wando River, by an r.i. determination of $\alpha = 1{\cdot}531$. Here porphyroblasts of green actinolite free from inclusions are accompanied by a little biotite and chlorite. Ghosts of the original plagioclase laths may just be visible in the groundmass with albite, carlsbad and pericline twinning (Nos. 7854, 7855, 7856, 7857). Basic dykes from the almandine zone in the Wando River are either homogeneous in texture or show a tendency to segregation layering into alternating hornblende and plagioclase bands. The groundmass now consists of a mosaic of xenoblastic untwinned plagioclase (Nos. 7872, 7873). The composition of the plagioclase is doubtful but a moderate relief suggests it to be more basic than albite. Granules of sphene and iron ore are restricted to the groundmass. Quartz is rare. Porphyroblasts of green actinolite may exceed 1 cm. in length.

The amphibolites show little change in texture as the grade of metamorphism increases. Garnet has not been detected in an igneous amphibolite. The composition of plagioclase tends to be quite basic and a maximum extinction angle for albite twins sectioned normal to (010) of 34° corresponds to labradorite in a clinozoisite-amphibolite from the Wando River (No. 7912). Veins containing microcline and clinozoisite have been found in amphibolites from the staurolite zone (No. 7910).

3. Serpentinized Peridotite

Peridotite dykes have intruded bedrock slates in close proximity to dolerites in Steep Bank Rivulet and in Mitchell's Creek west of the biotite isograd. These dykes dip steeply to the south-west in conformity with the cleavage and bedding of the slates.

The massive peridotite is dark blue-green in the hand specimen and outlines of olivine crystals reaching 6 mm. are visible on weathered surfaces. Hutton (1936, p. 241) concluded that of the serpentine minerals only chrysotile and antigorite possess distinctive optical features, the former being fibrous and optically positive with positive elongation, and the latter negative with positive elongation and a typical occurrence in tabular flakes with (001) cleavage.

In section No. 7820 (Plate XI, fig. 5) colourless fibres of chrysotile completely replace the olivine. Diopsidic augite makes up about 10 per cent of the rock and is sharply separated from brown hornblende, the boundaries of which are occasionally fringed with colourless tremolite in optical continuity. Diopside and hornblende poikilitically enclose rounded patches of chrysotile. Parallel strings of magnetite octahedra in the serpentine may represent the cleavage planes of original orthopyroxene. Talc and magnesite also occur.

The serpentinized peridotite has been altered at the boundaries to talc schists several yards in thickness, which retain none of the original texture of the peridotite in thin section. These schists consist almost entirely of fine flakes of talc. Only a little chrysotile remains and the relict shaped olivine crystals have been destroyed. Rhombs of magnesite and a little green chlorite, apatite and iron ores are present. Ultrabasic dykes in Steep Bank Rivulet are traversed by veins of chrysotile asbestos.

4. The Hummocks Serpentinite

Following brief references by Dennant (1885) and Krausé (1886), Dennant in 1893 noted that the rock at the Hummocks consists essentially of serpentine. He regarded the serpentinite as an altered lava, an origin supported also by Skeats (1909).

At the Hummocks, a ridge of serpentinite trends NW-SE and rises to a height of 250 ft. above the valley floor. Outcrops of serpentinite and of the rocks which adjoin it to the north-east are to be found in the gorge of the Wando Vale Ponds and at the site of the crushing plant where the rock is quarried for use as road metal, but the full extent of the various older rocks is obscured by alluvium to the south-west and by Jurassic mudstone to the north and south (Fig. 1).

The fresh serpentinite which can be observed at the Hummocks Quarry is massive, non-foliated and deep bluish-green in colour. This rock consists almost entirely of antigorite serpentine (Section Nos. 7858, 7859, 7860). Colourless flakes of antigorite reaching 0·4 mm. occur singly or in radiating sheafs showing a characteristic bluish tint in the grey interference colours. In places antigorite flakes are developing within areas of a different serpentine mineral marked by very weak birefringence and by a fine fibrous texture leading to wavy extinction (Plate XI, fig. 6). This mineral may be bastite, representing an orthopyroxene poor in iron. A few flakes of green serpentine are found with idioblastic magnesite and a little talc. The transformation of bastite to antigorite has been described by Benson (1913) for rocks of the Great Serpentine Belt of New South Wales. Serpentine occurrences extend to the north of the Hummocks for a distance of two miles. These consist essentially of antigorite (No. 7861) and correspond closely with the mineralogy of the Hummocks rock.

The quarry face at the Hummocks contains also:

1. *Magnesium carbonate veins.* Veins of carbonate up to 2 cm. in width show a symmetrical growth banding along the length of the vein. (Spec. No. 7861A.)

2. *Chrysotile asbestos.* Veins of fibrous chrysotile asbestos reach 2 ft. in thickness and have developed in planes of movement within the serpentinite. These veins are restricted to the body of the serpentinite and do not extend into the country rocks.

3. *Talc veins.* Weathered talc rocks are abundant along the edges of small shears which dissect the serpentinite.

4. *Chlorite-magnetite rocks.* Chlorite rocks containing octahedra of magnetite are formed as narrow dykes associated with talc rocks in shears, and closely resemble the "blackwall" described by Hess (1933b, p. 640). Green chlorite flakes in section No. 7862 from the quarry reach 0·05 mm. and contain octahedra of magnetite up to 4 mm. and minute shapeless iron ore grains. Porphyroblasts of talc may be present in similar rocks (No. 7863).

Nodules and veins of chalcedony are found just within the serpentinite on the south bank of the Wando Vale Ponds and on the eastern slopes of the Hummocks ridge. Skeats (1909) records a bedded chert "on the flanks of the hill". During the present field work no example of a bedded chert has been found in the Hummocks area, and unless Skeats's statement applies to veined chalcedony on the flanks of the Hummocks ridge, the only explanation is that he identified as chert the microcrystalline quarzite which outcrops three miles to the north on Cashmere Hill.

At all places where the boundary of the serpentinite can be examined talc schists outcrop. A talcose serpentinite from the gorge of the Wando Vale Ponds (No. 7864) contains flakes of talc derived from antigorite, a little of which remains in the section, with idioblastic magnesite and, rarely, iron ores.

In the gorge of the Wando Vale Ponds, a dyke 20 ft. in thickness and intrusive into biotite schists at a distance of ten chains from the edge of the serpentinite consists of crushed plates of chequer albite up to 3 mm., accompanied by tiny flakes of muscovite with accessory quartz and sphene. Albitite dykes in association with serpentinites have received mention by Hess (1933b, p. 650) and the processes of segregation from the ultrabasic rock or of modification of granite pegmatites advanced as explanation. The absence of granite pegmatites of such dimensions in other localities suggests that this albitite forms a part of the peridotite suite.

Although Skeats (1909) regarded the Hummocks rock as a lava, the absence of primary vesicular structures and the similarity in form to ultrabasic intrusives illustrating the "talc deposit" type steatitization described by Hess from Vermont (1933b) is taken as evidence of an intrusive origin. In the idealized diagram by Hess talc replaces serpentinite at the edges of the intrusion and in a keel below it, while a broad aureole of chloritic sediments extends above the lens.

The talc deposit type of alteration is believed to result from peridotite and the soapstone type from granular pyroxenite or hornblendite. The peridotite dykes of Steep Bank Rivulet are thus probably equivalent to the Hummocks serpentinite.

C. Retrogressive Schists

Rocks which contain low grade mineral assemblages within areas of high grade schists attest to retrogressive changes with the waning of temperature. Examples have been described of the alteration of staurolite and of andalusite to sericite. A series of sections illustrates the successive steps by which rocks composed of hornblende or actinolite are changed to talc rocks by way of tremolite and chlorite. Hess (1933a) has attributed these changes to hydrothermal alteration, but the occurrence in the Wando area of low grade assemblages in narrow zones suggests that shearing has also been an important factor in retrogression.

A cataclastic tremolite-chlorite schist (No. 7914) from the Hummocks contains porphyroclasts of colourless tremolite, with faint cores of hornblende, surrounded by shreds of chlorite flakes. Actinolite-chlorite schist (No. 7915) from the staurolite zone in the Wando River consists of a felted groundmass of pale green chlorite flakes containing prisms of green actinolite and granules of iron ore. A tremolite-chlorite-talc-carbonate schist (No. 7916) represents a further step towards soapstone.

An increase in the quantity of talc results in tremolite-chlorite-talc schists such as No. 7917, in which sheafs of colourless tremolite are set in a mass of minute talc flakes, chlorite and iron ore granules, and No. 7918, a talc-chlorite rock from Beauty Creek. Here the elongated shapes of aggregates of talc flakes suggest that they have replaced tremolite or actinolite.

These rocks are regarded as the retrogressive products of hornblende schists and amphibolites derived in their turn from dolerites.

D. Granitic and Associated Rocks

In the area north of Casterton two major groups of granitic rocks are found. The Wando Granodiorite includes four occurrences of granodiorite in the Wando Vale district which are taken to be representatives of a single batholith. The Dergholm Granite on the other hand is a true granite which outcrops over a wide area near Dergholm.

The Wando Granodiorite

Apart from the two main strips of granodiorite in the Wando Vale district, two smaller occurrences of gneissic granodiorite, each only a few square yards in extent, outcrop in the valleys of Vines Creek and Robertson Creek. Of the two main

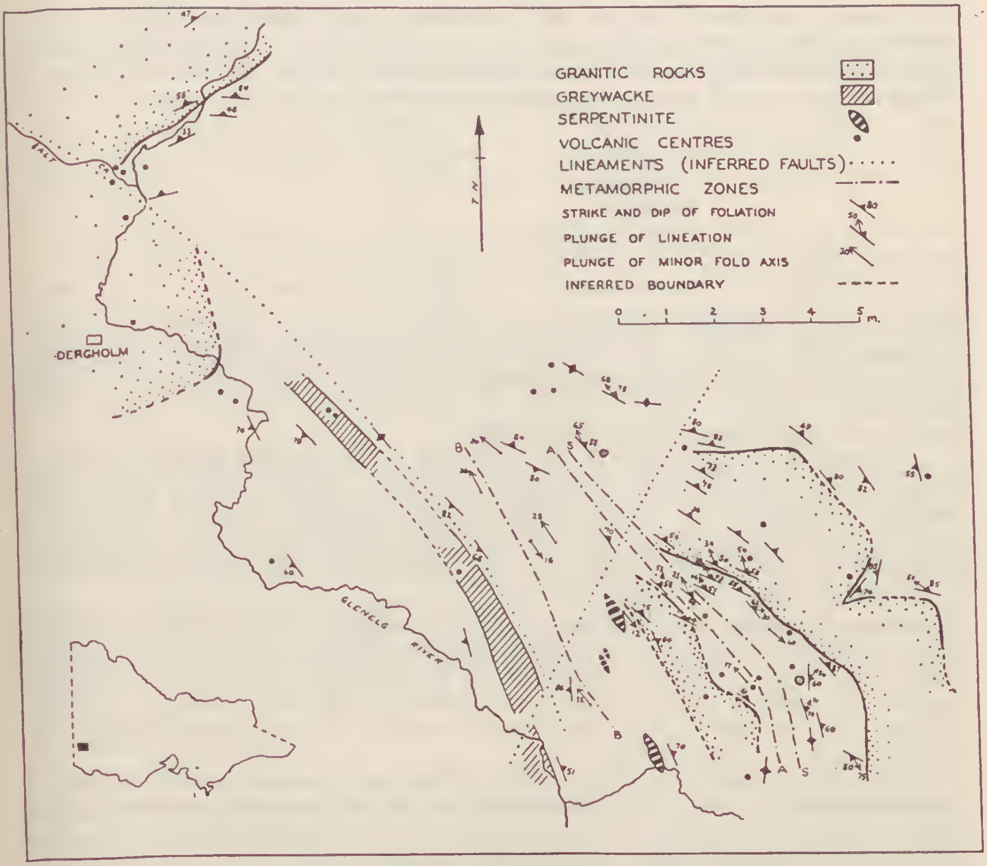

FIG. 4.—Structural map of the Dergholm-Wando Vale area.

granitic masses, the northern one is strongly foliated at its north-western end and is there characterised by abundant biotite and hornblende. Towards the centre of the mass the rock becomes less basic and free from planar structures. Here the granodiorite is coarse and even-grained with an approximate mode (No. 7919):

Quartz	40·0% by vol.
Oligoclase	34·1
Potash felspar	24·0
Muscovite	1·9
Biotite	—
Apatite	tr.
	100·0

The predominant potash felspar is orthoclase, but this may be accompanied by a little microcline. Oligoclase exhibits both albite and pericline twinning and occasionally shows myrmekite structure. The felspars enclose blebs of quartz, but the characteristic occurrence of quartz is in round aggregates almost 1 cm. in diameter.

Except in the north-west of this granodiorite mass, non-foliated granodiorite outcrops at the boundaries. Examples of the gneissic rock from the Wando River (No. 7922) contain epidote as well as biotite and hornblende and the mode may be compared with that of the leuco-granodiorite above:

Andesine	42·7% by vol.
Quartz	27·6
Biotite	18·9
Hornblende	6·2
Epidote	3·8
Apatite, sphene	0·8
	100·0

Zoned andesine, slightly sericitized and with albite and pericline twinnnig, may be accompanied by a little orthoclase. Quartz and the felspars generally show signs of granulation. Biotite flakes, accompanied by chlorite, reach 4 mm., while hornblende prisms reach a length of 5 mm. Stumpy prisms of epidote are sieved with quartz, and apatite and sphene are accessory.

The massive rock from the St. Elmo quarry in the southern granodiorite mass is of medium grain size and pinkish-grey in colour, and contains oligoclase and poikilitic microcline with quartz, biotite, epidote, muscovite, apatite and sphene. At the edges of the igneous mass this granodiorite is foliated and granulation of the quartz and sericitized andesine is marked. Section No. 7924 shows an abundance of epidote but contains no hornblende.

Schists adjacent to granitic intrusions. As the boundary of the northern intrusion is approached from the south in the valley of the Wando River schists containing biotite, muscovite, andesine and quartz show the first signs of a lit-par-lit structure produced by narrow granitic veins at a distance of 60 yds. from the intrusion. Gneissic veins then predominate until schists remain only as narrow ribbons within the foliation plane of the gneiss.

Schists at the contact may be enriched in tourmaline and muscovite. Muscovite porphyroblasts in section No. 7926 comprise the major part of the rock and contain quartz and biotite inclusions. The porphyroblasts accompany biotite and sieved brown tourmaline in a matrix of xenoblastic quartz.

Quartz-tourmaline veins are found up to a mile from the granodiorite boundary and in several localities tourmalization of schists has led to the assemblage quartz-tourmaline (Harker, 1937, p. 118). An example of this assemblage is afforded by section No. 7928 in which folded micro-structures resemble those of adjacent biotite schists. A refractive index value of $\omega = 1{\cdot}637$ for the yellow tourmaline in this rock suggests a magnesian composition.

Dykes associated with the granodiorite. Dykes of quartz diorite reaching a thickness of several yards are intruded into the foliation planes of schists along the southern border of the northern Wando Granodiorite mass, extending from the Wando River south-east to Corea Creek. A sample of quartz diorite (No. 7929) from the Wando River contains:

Medium andesine	48·6% by vol.
Quartz	23·1
Hornblende	17·8
Biotite, chlorite	9·9
Apatite, sphene	0·6
	100·0

Prisms of twinned hornblende, associated with chloritized biotite, define a pronounced linear structure which, in Corea Creek, plunges steeply to the south-west at angles of from 50° to 70°. Intrusive breccias of quartz-diorite containing many inclusions of quartz and biotite schist are found in Corea Creek at locality 48.5, 72.5.

Fine-grained quartz microdiorites in Corea Creek are probably related to the coarser quartz diorites and contain needles of hornblende in the process of replacement by biotite and iron ores. Quartz and acid labradorite of the groundmass show partial granulation.

A fine-grained greenish grey microdiorite which contains phenocrysts of andesine is poorly exposed in the valley of the Wando River. The zoned sericitized phenocrysts reach 3 mm. and are contained in a groundmass of twinned and zoned andesine laths of an average length of 0·2 mm., accompanied by biotite, muscovite, sphene and secondary chlorite and rutile. Phenocrysts of hornblende have been replaced by chlorite and calcite (Nos. 7931, 7932). The intrusive nature of these rocks is confirmed in Steep Bank Rivulet, where a dyke of similar rock occupies a cross-joint.

Dykes of aplite and pegmatite are largely restricted to the body of the granodiorite and gneiss except in the gorge of Corea Creek where dykes are intrusive into country rocks in much greater abundance than into the adjacent granodiorite. Two varieties of aplite are found, one containing deep brown pleochroic tourmaline and colourless garnet with muscovite, biotite, quartz, microline and oligoclase (No. 7934) and the other free from tourmaline and garnet (No. 7935). The aplites of the second type are of finer grain than those of the first and have textures which tend to the true saccharoidal texture of the aplites, but nevertheless differ markedly in thin section from the quartzofelspathic schists, which they may outwardly resemble.

The Dergholm Granite

Granite from the quarry four miles south-west of Dergholm is coarse-grained and non-foliated, and contains pinkish perthite averaging 1 cm. in length, oligoclase, grains of smoky quartz, and a little biotite. The rock is a true granite and contains a little purple fluorite visible in section No. 7936. Non-foliated granite outcrops to the east and south of the town and also in the valley of Salt Creek further to the north. On the west bank of the Glenelg River, Caldwell has mapped granite and hornblende gneiss. There is no sharp boundary between these two, a gradual development of foliation and increase in the proportion of biotite and hornblende taking place east of Capaul Homestead. The boundary of the intrusion here strikes NE-SW along the valley of the Glenelg River.

Mawson and Segnit (1945), in a description of granites from Tintinara, 160 miles north-west of Dergholm, include a chemical analysis of the Dergholm Granite and on the basis of this and the heavy mineral content regard it as part of a large batholith extending into Victoria from South Australia. The presence of fluorite in the Dergholm Granite supports this link.

Schists of the Glenelg River Complex which outcrop along the Glenelg Valley north of Dergholm resemble the rocks of the Wando area but no attempt has been made to trace metamorphic zones. To the south-east of Capaul sedimentary rocks are represented by quartz-muscovite schists and by calc-silicate rocks containing hornblende and diopside. Meta-dolerites outcrop on the east bank of the Glenelg River and here also are found boulders of quartz-gabbro (No. 7948) in which original pyroxene is preserved.

It is not known to what extent the Dergholm Granite has contributed to the metamorphism of these rocks. Metamorphism of slates by the Dergholm Granite at a locality in the Glenelg River valley E.S.E. of Dergholm has been only slight, resulting in induration and the growth of minute biotite flakes. This fact, together with the marked difference in appearance between the Dergholm Granite and the Wando Granodiorite and the presence of fluorite in the former but not in the latter suggests that the Wando Granodiorite preceded the Dergholm Granite and was responsible for the major metamorphic effects over the whole. Fine-grained granodiorite similar to the St. Elmo quarry rock outcrops in Schofield Creek, south-east of Harrow, and an extension of the field mapping in this direction may indicate more definitely the relation between the two granitic groups.

E. Permian Tillite and Younger Rocks

Tillites were recorded at Wando Dale by Hogg in 1898, but several small occurrences have been found in the Wando Vale area itself. In the valley of Boundary Creek tillites rest unconformably on biotite-quartz schist and on granodiorite gneiss, and contain boulders of gneiss, schist and slate typical of the Glenelg River Complex.

In the south-east of the area gently dipping mudstones form the northern end of a triangular area of Merino Group sediments which are mainly of Jurassic age and rest with angular unconformity upon slate, schist and granodiorite (Kenley, 1954).

A yellowish-brown limestone has been mapped near the junction of Steep Bank Rivulet and Vines Creek and is evidently that described by Ferguson (1894, p. 58) as occurring at Woodburn and containing a fauna of "Miocene aspect". Thin beds of flatly dipping arenaceous limestone also outcrop in this area but evidence of the age of this formation has not been found.

The Dundas Tablelands are capped by a veneer of Tertiary laterite which is obscured towards Dergholm by aeolian sands.

Many small flows of Tertiary Volcanic rocks occur at widely scattered points (Fig. 4) and embrace a range of rock types including olivine basalt, olivine nephelinite, and soda-rich trachyte. In the absence of fossiliferous Tertiary sediments in association with these rocks there is no clear subdivision into Older and Newer Volcanics.

Structural Geology

A. Country Rocks

Bedding. A fine bedding lamination, found in sedimentary rocks of all grades, shows strong drag folding in places, but field mapping has not revealed the overall structure.

The graded bedding of graywackes in the Harvester Creek gorge indicates that the top of the formation lies to the south-west and that the beds are not overturned. This graywacke is thus overlain by the slates, which outcrop to the south-west. Further mapping of the greywacke formation is likely to provide the clue to the major structure, but to the north-east the stratigraphic picture is complicated by the increasing metamorphism and by faulting in Steep Bank Rivulet. The presence of carbonates in the fine beds of the graywacke suggest that pre-graywacke limestone or dolomite existed.

Foliation. Under this heading are grouped the axial plane cleavage in low grade slates and the schistosity of higher grade schists, the latter defined by the preferred orientation of platy minerals such as biotite and muscovite, by flattened calcite grains in calc-biotite schist (section No. 7826), and by rosettes of hornblende needles in hornblende garbenschiefer. Moreover, hornblende metacrysts in basic dykes are flattened in the plane of foliation.

The trend of foliation and the boundaries of rock types are frequently parallel. Thus in the Wando River gorge boundaries between staurolite schist and hornblende schist, and between biotite schist and calc-silicate rocks, trend NW-SE, which is also the strike of the foliation plane. Rupturing movements do not appear to have taken place along these planes, which probably reflect original bedding planes, tightly folded.

Foliation trends fairly uniformly over the whole area in a NW-SE direction but in the south tends to change to north-south. In the area north of Dergholm, near the edge of the Dergholm Granite, foliation in the country rocks strikes east-west. The dip of the foliation is uniformly steep, rarely assuming values below 50°. In the Wando River area the direction of dip is consistently north-east, but towards the west the dip steepens to the south-west (Fig. 4).

Faults. Boutakoff (1952, p. 28) has presented the pattern of late Tertiary faults and lineaments in south-western Victoria. Two of his postulated linear trends, which are based upon the assumption that the Glenelg River Valley has been determined largely by fault lines, fall within this area, and there is evidence from the basement rocks that faulting has taken place in each case.

Shearing of sedimentary rocks and basic dykes and the crushing of serpentinized peridotite dykes in Steep Bank Rivulet suggest that the Salt Creek Fault may be extended to the south-east, passing to the north of the graywacke formation. Further evidence of this fault is found in the occurrence of a scarp of dolomitized breccia in Steep Bank Rivulet, outcrops of silicified breccia in Nolan Creek and a number of volcanic centres aligned on this trend.

The graywacke has been displaced along a NE-SW line two miles north-west of Retreat. Further, both the northern and southern Wando Granodiorite bodies appear to be abruptly terminated at their north-western extremities beneath the laterite cover. Having regard to the elongate form of these bodies, their virtual disappearance in the space of one mile suggests a pre-laterite fault along a NE-SW line.

Lineation. In biotite and garnet schists a lineation is produced by small puckers, by the elongation of biotite flakes and occasionally by a slight elongation of the quartz grains.

The attitude of the lineation of biotite flakes has been mapped at several points in the field (Fig. 4). The plunge of linear structures is generally directed between north-west and north-east but the angles of plunge vary widely between 30° and 70°. In the south, steep plunges to the south-east are encountered.

Folds. The attitudes of minor fold axes can be measured directly and trend NW-SE, with plunge angles, in the case of slates and phyllites, generally less than 30° to the north-west. At higher grades, complex fold profiles are found in calc-biotite schists and in argillaceous rocks. Here plunge angles of folds may reach as much as 60° and are usually sub-parallel to the lineation of biotite flakes.

Mullion and boudinage structures. Mullion structure, of which examples are found at the head of Corea Creek Gorge, is illustrated in Pl. XII, fig. 1. A ribbed structure several feet in length is made up of prisms of hard diopside-plagioclase-quartz rock, pod-shaped in cross-section, which are adjoined by biotite schist and plunge steeply to the south-east. The structure is classed as cleavage-mullion (Wilson, 1953), the pod-shaped cross-section having been controlled by intersecting cleavage and bedding (Fig. 2A).

Dykes of micro pegmatite in the gorge of Corea Creek exhibit boudinage structure in which the long axes of the boudins plunge steeply to the south-east (Pl. XII, fig. 2). Since measurable fold axes at this locality also plunge steeply to the south-east, both mullion and boudinage are regarded as linear structures with extension in the b-direction.

Microfabrics of Biotite Schists

From two specimens of quartz-biotite schist, No. 7940 and No. 7941 from the respective localities 42.7, 79.5 and 43.3, 80.0, fabric diagrams have been prepared to indicate the orientations of biotite and quartz. In each case quartz occurs as a granoblastic mosaic of approximately equant grains which show faint strain shadows. Biotite flakes are slightly elongated to produce a lineation.

The poles of normals to (001) cleavage planes of biotite flakes and of optic axes of quartz are depicted in equal-area projections of the lower hemisphere. The poles of the geographical co-ordinates north and west have been incorporated in the diagrams.

Biotite diagrams for the specimens No. 7940 and No. 8941 are reproduced in diagrams A and C of Fig. 3. The diagrams show strong point maxima with densities of up to 16% but at the same time weak partially developed girdles of 1% density lie in the plane normal to the lineation. On the basis of the biotite fabrics the schists may be classed as B-tectonites.

The corresponding diagrams for quartz are B and D of Fig. 3. Diagram B reveals no clear preferred orientation. Diagram D contains a cleft girdle in the a-c plane, normal to the lineation. The diagrams C and D taken together confirm the rock as a B-tectonite in which the lineation has the significance of the b-fabric axis.

Maxima reaching 3% are arranged somewhat symmetrically in the four quadrants of diagram D but there is a tendency to monoclinic symmetry.

b-lineations thus plunge to the north-west at steep angles, occasionally in excess of 50° in the area for which diagrams were prepared. This direction of plunge accords with the orientation of fold axes measured in rocks of lower grades, but the angle of plunge in the case of the lineation is rather greater than that of fold axes in slates.

However, the occasional divergence of pucker axes from lineations of elongated biotite flakes suggests that a-lineation may occur in schists from this area. Thus in hand specimen No. 7943 these two linear structures make an angle of 30° in the foliation plane. The lack of preferred orientation in the quartz of section No. 7940 (Fig. 3B) might be due to destruction of an original girdle pattern by later movements resulting in a displacement of quartz maxima towards the centre of the diagram, though the relatively strain-free nature of the quartz argues against this possibility.

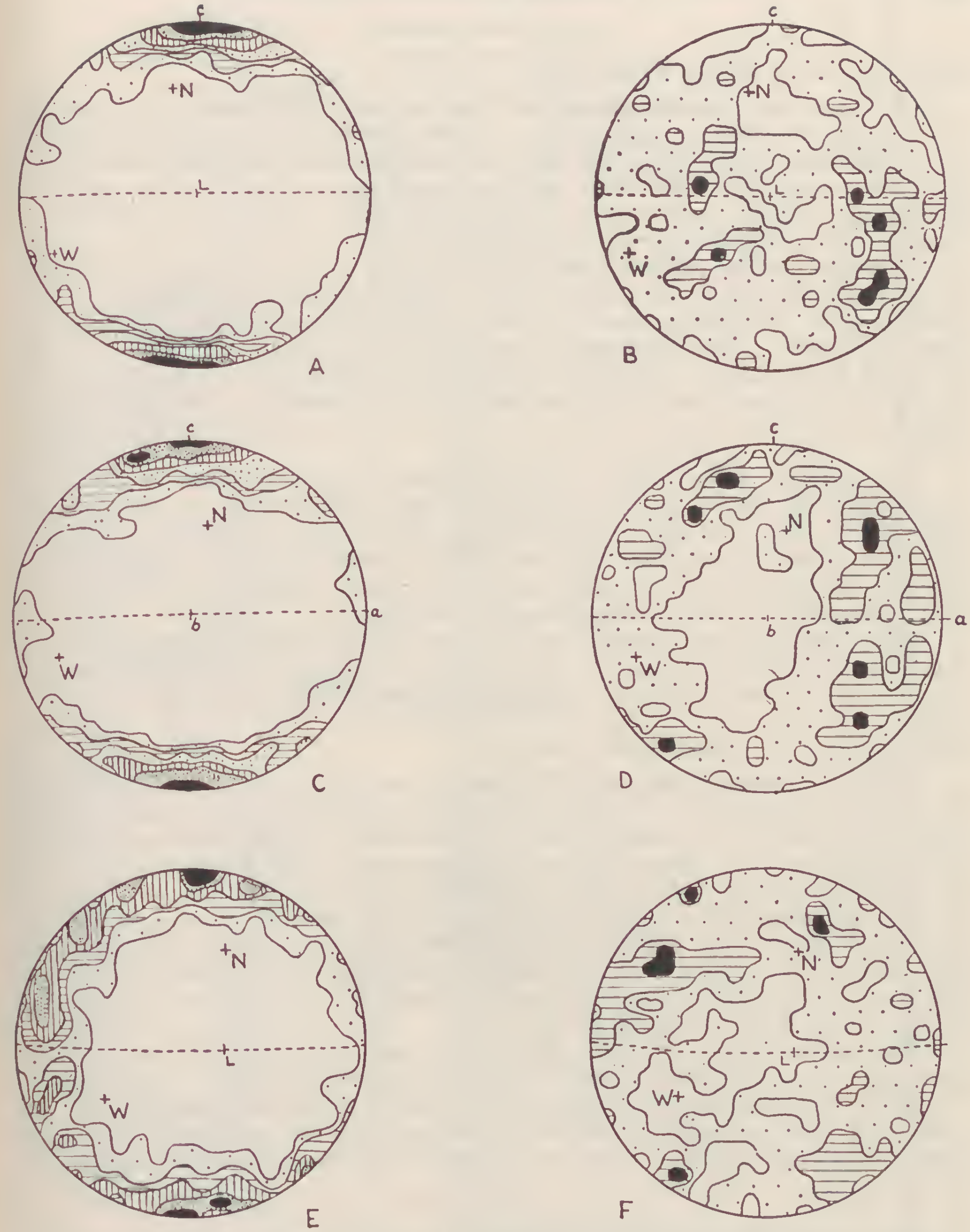

FIG. 3.—Preferred orientation of biotite and quartz in schist and in granodiorite gneiss.

A. Poles of (001) for 300 biotite flakes in quartz-biotite schist. Lineation L. Contour 16-13, 12-9, 8-5, 4-3, 2, 1, 0% per 1% area.
B. Corresponding diagram for 300 quartz optic axes. Contours 3, 2, 1, 0% per 1% area.
C. Poles of (001) for 300 biotite flakes in quartz-biotite schist. Lineation b. Contours 13-10, 9-7, 6-5, 4-3, 2, 1, 0% per 1% area.
D. Corresponding diagram for 300 quartz optic axes. Contour 3, 2, 1, 0% per 1% area.
E. Poles of (001) for 300 biotite flakes in granodiorite gneiss. Lineation L. Contours 6-5, 4, 3, 2, 1, 0% per 1% area.
F. Corresponding diagram for 300 quartz optic axes. Contours 3, 2, 1, 0% per 1% area.

(Foliation plane dotted in each case.)

B. Granitic Rocks

Structures in the Wando Granodiorite

The non-foliated granodiorite differs from the gneiss in its scarcity of structural features. In the absence of phenocrysts or basic clots few platy or linear structures can be measured in the field. The gneiss on the other hand possesses a prominent foliation defined by biotite flakes and hornblende prisms. At its edges the non-foliated granodiorite is strewn with unoriented schist xenoliths, as at Robertson Creek, which indicate magmatic emplacement.

Where the gneiss adjoins quartz-biotite schists in the Wando River the attitude of the foliation plane of the gneiss agrees closely with that of the foliation of the country rocks. Within the gneiss, tabular xenoliths of schist occupy the foliation plane. Moreover, a linear structure is defined within the plane of foliation of the gneiss by the attitude of elongate inclusions oriented with their long axes parallel. In the valley of the Wando River the plunge of this lineation to the north-west at angles of up to 50° compares closely with that of the b-lineation in neighbouring schists.

The intrusion of the igneous mass has evidently led to some disturbance of the schist foliation. In the sharp indentation in the northern edge of the northern granodiorite body the schistosity, which elsewhere strikes NW-SE, is directed NE-SW. Although variations in trend of schist foliation have been produced, there is no evidence of its vertical disturbance with upward movement of the magma. The schistosity dips steeply throughout the area.

The foliation plane of schists has thus provided the structural control for the emplacement of the granodiorite. The southern boundary of the northern mass is a gently curved surface closely following the trend of schistosity (Fig. 4).

Microfabric of the Granodiorite Gneiss

Figures 3E and 3F represent biotite and quartz fabrics of granodiorite gneiss (No. 7942) collected from locality 43.4, 80.1, in the northern granodiorite body. The section was cut in a plane normal to the lineation. The biotite diagram contains a closed girdle of 1% density within the plane normal to the lineation. The maximum density is 6% at c, but sub-maxima of 4% are spread round the girdle.

The specimens No. 7941 and No. 7942 of schist and gneiss respectively were collected in the Wando Valley from points only fifty yards apart. Comparison of the diagrams C and E indicates the similar orientation of the linear structures in either case and the more complete closure of the girdle and presence of sub-maxima in the case of the granodiorite gneiss.

The quartz diagram Fig. 3F contains evidence of a weak girdle pattern in the plane normal to the lineation, with maxima of 3% density.

These diagrams suggest either that the gneiss has been produced from the sediments by a metasomatic process or that deformation subsequent to granitic intrusion has affected both sediments and granite and has led to similar orientation of structures.

Structures in Aplite and Pegmatite Dykes

Dykes of aplite and pegmatite in Corea Creek gorge intersect folded schists and are exposed in the bed of the stream. Diopsidic calc-silicate rocks at either end of the gorge bound a central area of semi-pelites rich in biotite. Axes of minor folds plunge to the south-east.

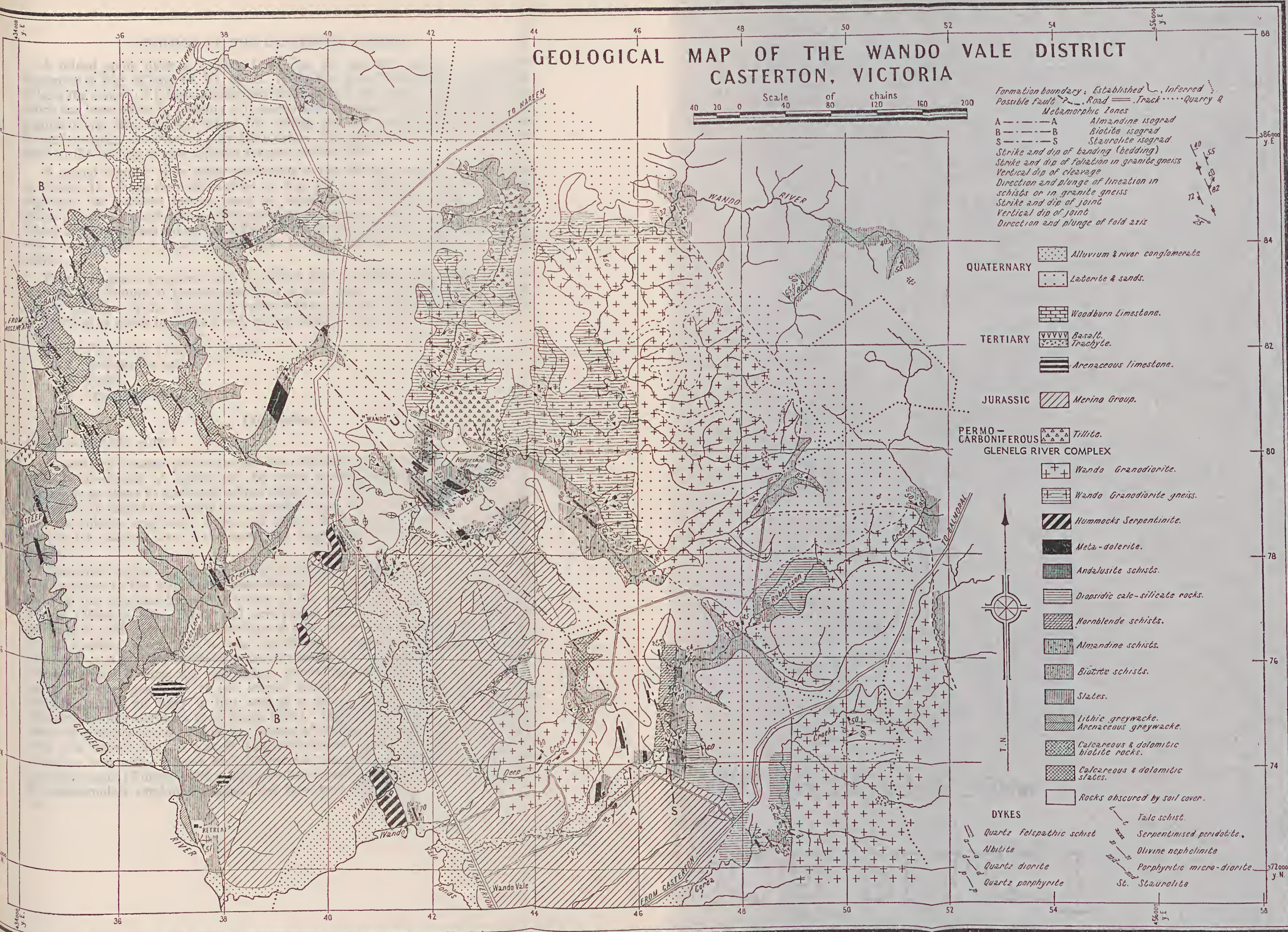

Fig. 5.—Geological map of the Wando Vale district, Casterton, Victoria.


GEOLOGICAL MAP OF

A folded aplite dyke at locality C in Fig. 2B has the relation to pegmatite illustrated in Fig. 3C and Pl. XI, fig. 3. The aplite dyke, three inches in thickness, reflects the course of folded sedimentary bedding and cuts across a pegmatite dyke which has been offset by bedding slip movements associated with the folding. The pegmatite was thus injected before the folding and this relationship is confirmed by the boudinage structure of pegmatitic dykes. The aplite has been either injected prior to the folding or else injected between folded beds.

A second example of an aplite conforming to the attitude of folded beds is found at locality D, where the relationships of Fig. 2D are observed. Here an earlier pegmatite has suffered tension along its length to allow the injection of aplite, which occupies a joint plane. Mineralogical differences confirm the fact that the folded and non-folded aplites are different, the former being characterised by richness in tourmaline. A quartz-diorite dyke has been intruded subsequently to both aplites.

Fabric diagrams prepared from the folded and non-folded aplite dykes show an isotropic distribution of quartz optic axes in both cases. This is evidence of post-folding injection of the tourmaline aplite between already folded beds. The order of injection of dykes in Corea Creek is thus likely to have been:

1. Pegmatite (folding period)
2. Tourmaline aplite
3. Aplite
4. Quartz diorite.

Conclusion

The Metamorphic Zones

A series of metamorphic zones has been described in which stress minerals are typically developed. A feature of the zones is their narrow lateral extent, the passage from slates to staurolite schists taking place over a distance of three miles. The entry of staurolite restricts the almandine zone, which is narrow in comparison with the chlorite and biotite zones and differs in this respect from the almandine zone in the classical area of the south-east Highlands of Scotland (Harker 1937, p. 209).

Staurolite schists and andalusite-free garnetiferous schists in the Wando Vale area conform to the equilibrium assemblages for pelitic and for partly calcareous rocks in the staurolite-kyanite subfacies of the amphibolite facies as recorded by Turner (1948, p. 82). Pelitic and semi-pelitic rocks relatively poor in lime and potash have, under conditions of medium to high grade metamorphism, accompanied by deformation, given rise to the assemblages plagioclase-muscovite-staurolite-almandine-quartz and plagioclase-muscovite-biotite-almandine-quartz. With higher concentrations of lime the assemblage plagioclase-hornblende-almandine-biotite-quartz has been produced at one known locality. It is therefore unlikely that staurolite makes an entry in this area at a metamorphic grade lower than the staurolite-kyanite subfacies (e.g. Barth 1936). The limited width of the almandine zone may possibly be due to faulting. Schists which contain almandine in the Wando Vale area appear also to contain plagioclase more basic than albite. Since the transition from albite to more basic plagioclase takes place in the upper part of the almandine zone (Turner 1948, p. 89), the lower part of this zone, corresponding to the albite-epidote amphibolite facies, may have been faulted out.

There can be little doubt that the rocks of all metamorphic grades have developed from the same original complex. Thus, putting aside the question of age, the statement by Dunn (1912, p. 116) "At the Wando Gorge . . . schists that probably represent Ordovician beds . . . occur" finds complete support, while the conclusion of Stirling (1898, p. 86) "I was unable to note any contact of the gneissose schists to the east with these sediments, but from the rather abrupt change it is probable that the former are altogether older" is incorrect. Although the change is rather abrupt it is nevertheless a progressive change.

The Growth of Antigorite

In the Steep Bank Rivulet area, where peridotite has been strongly sheared, chrysotile is the stable serpentine mineral. Antigorite has not been produced and the peridotites are intrusive into slates which occupy a position low in the greenschist facies. Shearing alone has been insufficient for the production of antigorite. The antigorite serpentinites at the Hummocks lie within an area of biotite schists and it is thus likely that the growth of antigorite has accompanied the main metamorphism. The metamorphic grade at which the change chrysotile → antigorite has taken place appears to be near the middle of the chlorite-biotite subfacies of the greenschist facies. This may be compared with the estimate of Hess, Dengo and Smith (1952, p. 74), who place the grade at which this change occurs above the chlorite-biotite subfacies in a position equal to or a little lower than the albite-epidote amphibolite facies.

Intrusion of the Wando Granodiorite

The broad parallelism between the biotite, almandine and staurolite zones and the northern mass of the Wando Granodiorite suggests that the attitude of the zones has been determined by the intrusive mass, whose emplacement was controlled by the regional schistosity. Field evidence such as the folding and boudinage structure in acid differentiates suggests that fold movements continued until after intrusion of the granodiorite. The presence of the almandine and staurolite zones suggests that compression and shearing stress during folding were accompanied by increased temperatures, possibly resulting from igneous action at depth.

Although the parallelism of basic and ultrabasic dykes with the cleavage of slates could suggest their intrusion into the cleavage plane, the similar orientation of cleavage and bedding over much of the area allows the possibility that these dykes are pre-folding. The relative age of basic dykes and quartz-porphyrite dykes is unknown.

A series of low to medium grade schists of argillaceous or sandy character, the Kanmantoo Group, is exposed on the eastern flanks of the Mount Lofty Ranges in South Australia. Bowes (1954) has described from Encounter Bay andalusite, cordierite, albite and chlorite schists produced within the aureole of an intrusive granite from quartz-biotite schists of the Kanmantoo Group. Although Mawson and Parkin (1943) suggest a Precambrian to late Cambrian age for this granite, and also for the Dergholm Granite to which it is related, Bowes favours a mid-Ordovician age. The age of the Kanmantoo Group has been suggested as Lower Palaeozoic (Bowes 1954, p. 184) but the relation between the Kanmantoo Group and the Glenelg River Complex is quite unknown.

Age of the Glenelg River Complex

In the absence of fossil evidence from the slates of this area the problem of the age of the Complex remains unsolved.